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Clinical Investigation

Pilot Comparison of Three Cardiopulmonary Resuscitation Medication Dosing Strategies in Overweight Children

Lyndsy E. Pinchevsky, PharmD,[1,2] Kimberly A. Pesaturo, PharmD,[3,4] Brian S. Smith, PharmD,[4] and Christian A. Hartman, PharmD[4]

[1]Department of Pharmacy, Burke Medical Center, Burke Virginia, [2]Department of Pharmacy, Kaiser Permanente, Washington DC , [3]Department of Pharmacy Practice, Massachusetts College of Pharmacy and Health Sciences, Worcester, Massachusetts, [4]Department of Pharmacy, UMass Memorial Medical Center, Worcester, Massachusetts

OBJECTIVES Dose calculations using three variations of patient weight estimates (actual body weight [ABW], ideal body weight [IBW], and the Broselow Pediatric Emergency Tape [BPET, a length-based weight estimation tool]) were compared to administered doses of cardiopulmonary resuscitation medications in overweight and obese children to assess for differences in dose.

METHODS This retrospective cohort analysis included 54 consecutive pediatric patients who underwent emergency resuscitation at UMass Memorial Medical Center between January 2000 and October 2008. Patients were identified using ICD-9 codes related to cardiopulmonary resuscitation. Patients were included if they were overweight or obese, less than 12 years of age, less than 146 centimeters in length, and received emergency resuscitation medication(s). Doses of administered medications were recorded and compared to potential doses calculated based on ABW, IBW and the dose recommended by the BPET. Dose differences greater than 10% were considered clinically significant and dose differences greater than 20% were considered to be potential medication errors.

RESULTS Out of 54 possible patients, four overweight patients were included; none were obese. Ten total medication doses were assessed (minimum two per patient). In all patients, at least one comparator dose varied by greater than 20% from the administered dose. Four out of 10 doses calculated according to ABW, eight out of 10 doses calculated with IBW, and eight out of 10 doses recommended by the BPET all differed by greater than 20% from the administered dose.

CONCLUSIONS Dosing variations were observed when the dose received was compared to dosing using three variants of patient weight estimates. The largest dosing differences were observed upon comparison of the administered dose versus the dose recommended by the BPET.

KEYWORDS emergency, medication errors, overweight, pediatrics, resuscitation

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INTRODUCTION

Length-based weight estimation tools are used in pediatric emergency resuscitations to estimate patient weight when it is impractical or difficult to accurately weigh the child on a scale.[1] These tools are useful in helping guide the practitioner to the correct size medical equipment and to administer appropriate resuscitation medication doses. The American Heart Association's

Address correspondence to: Kimberly A. Pesaturo, PharmD, BCPS, Department of Pharmacy Practice, Massachusetts College of Pharmacy and Health Sciences, 19 Foster Street, Worcester, MA 01608 email: kimberly.pesaturo@mcphs.edu

ABBREVIATIONS ABW, actual body weight; AHA, American Heart Association; BPET, Broselow Pediatric Emergency Tape; IBW, ideal body weight; MAR, medication administration record; NHANES, National Health and Nutrition Examination Survey; NHCS, National Health Center for Statistics; PALS, 2005 Pediatric Advanced Life Support; UMMMC, UMass Memorial Medical Center; Vd, volume of distribution

(AHA) 2005 Pediatric Advanced Life Support (PALS) guidelines support the use of length-based weight estimation tools because they can reduce the need for clinicians and nurses to rely on memory during times of high stress.[2]

Dr. James Broselow developed the first length-based weight estimation tool in 1988, based on data from the National Health Center for Statistics (NHCS) showing that a child's ideal lean body weight correlated accurately with the child's length.[3] The Broselow Pediatric Emergency Tape (BPET, Broselow; Armstrong Medical Industries, Inc., Lincolnshire, IL) uses colored zones to provide drug doses, medication equipment sizes, and IV fluid volumes needed during an emergency.[3] The BPET is widely used and has been validated in both ambulatory and simulated emergency situations.[1]

Despite the BPET's widespread use in pediatric emergencies, there are concerns regarding its validity in some pediatric populations. Studies have demonstrated that BPET's pre-defined weight categories may not be applicable to children in other countries,[1,4] that using pre-determined doses may lead to under-resuscitation of some patients based on early definitions of overweight children,[5] and that previous versions of the BPET may violate the Joint Commission's 2007 National Patient Safety Goal 3B requiring hospitals to standardize and limit drug concentrations for continuous intravenous infusions.[6]

The increasing trend in North America of childhood obesity lends concern to the continued applicability of the BPET in overweight and obese children. Since 1971, NCHS census surveys such as the National Health and Nutrition Examination Survey (NHANES), have calculated and recorded children's body mass indices (BMI).[7] As evidenced by the NHANES surveys, the prevalence of overweight children ages two through 19 years in the United States has steadily increased from 1988 to 2006, averaging 9.7% in the 1988–1994 data, 14% in the 1999–2002 data, and 15.7% in the 2003–2006 data.[8-12]

The color zones on the BPET are based on anthropometric reports.[12] The zones are designed to predict the 50th percentile weight-for-height, which is considered an estimate of ideal body mass.[13] Although the newest tape was released in 2007, its medication dosing and equipment size recommendations are based on average pediatric weight-for-height data from the 1995 NHANES census. Investigators have suggested that the BPET may not be appropriate in overweight children, but we are unaware of any studies focusing solely on the appropriateness of the BPET's recommended medication doses for overweight American children.[5] The primary objective of this study was to determine if differences exist between administered doses of resuscitation medications in overweight children and doses calculated according to three variations of patient weight estimates: actual body weight (ABW), ideal body weight (IBW) and BPET's standardized length-based weight estimation categories as compared to dose received. Secondary objectives included assessing dosing differences using three variations of patient weight estimates in obese children, determining the rate of occurrence of potential medication errors, and examining the proportion of patients whose ABW is not represented on the BPET.

MATERIALS AND METHODS

This was a single center retrospective cohort analysis. Study participants were electronically identified from the hospital patient information system using the following ICD-9 codes: 99.60 (cardiopulmonary resuscitation), 93.93 (non-mechanical methods resuscitation), 99.63 (closed chest cardiac massage), 37.91 (open chest cardiac massage consecutive resuscitation). Any overweight or obese pediatric patient admitted to UMass Memorial Medical Center (UMMMC) between January 2000 and October 2008 who was younger than 12 years of age and received one or more resuscitation medication(s) during an emergency resuscitation situation were included for study analysis. We defined a resuscitation medication as a medication recommended for use by the AHA during a cardiac emergency as outlined by the AHA PALS guidelines.[2] Patients were excluded if they were resuscitated outside of the pediatric emergency department or inpatient wards, or received resuscitation medication(s) but did not fit criteria for appropriate use of the BPET (i.e., they were 12 years of age or older, heavier than 36 kg or taller than 146 cm.[14] Patients with incomplete medication records were also excluded from the study. Current criteria uses Centers for Disease Control Growth Charts to define overweight and obese children.[15] A child aged 2 through 19 years is considered overweight

Table. Calculated Dose Derivations per Patient and Absolute Dose Differences

Pt.	Height* (ABW)	Medication	Actual dose given†	Dose using ABW†	Absolute dose difference: (ABW - actual %)	Dose using IBW†	Absolute dose difference: (IBW - actual %)	Dose using BPET†	Absolute dose difference: (BPET- actual %)
1	91.44 (11.1)	epinephrine	0.1	0.11	0.01 (10%)	0.14	0.04 (40%)	0.17	0.07 (70%)
		sodium bicarbonate†	10	11.1	1.1 (11%)	13.8	3.8 (38%)	16.5	6.5 (65%)
		amiodarone	60	55.4	-4.6 (7.67%)	69	9 (1.67%)	80	20 (33.3%)
		calcium chloride	220	221.6	1.6 (0.7%)	275.8	55.8 (25.4%)	330	110 (50%)
2	146 (40)	epinephrine	0.4	0.4	0 (0%)	0.35	-0.05 (12.5%)	0.33	-0.07 (17.5%)
		sodium bicarbonate†	50	40	-10 (20%)	35.2	-14.8 (29.6%)	33	-17 (34%)
3	52 (4.57)	epinephrine	0.1	0.04	-0.06 (60%)	0.04	-0.06 (60%)	0.4	0.3 (300%)
		sodium bicarbonate†	8	4.6	-3.4 (43%)	4.5	-3.5 (22%)	4	-4 (50%)
4	126 (32)	epinephrine	0.5	0.32	-0.18 (36%)	0.26	-0.24 (48%)	0.33	-0.17 (34%)
		atropine	0.5	0.64	0.14 (28%)	0.5	0 (0%)	0.5	0 (0%)

ABW, actual body weight; BPET, Broselow Pediatric Emergency Tape; IBW, ideal body weight
** height is in cm; weight is in kg*
†sodium bicarbonate doses are shown as mEq, all other doses are mg

when BMI-for-age is greater than or equal to the 85th and less than the 95th percentile; a child younger than 2 years is overweight when weight-for-recumbent length is ≥ 95th percentile. A child aged 2 through 19 years is considered obese if BMI-for-age is ≥ 95th percentile; the criterion for an obese child less than 2 years old is not defined.

Data collection was completed via retrospective medical record review. The study investigators located a copy of the resuscitation report in the patient's medical chart. The resuscitation report is a triplicate form used during resuscitations to record events, drug doses, and electricity administered. If no resuscitation report was available, the data was extracted from the medication administration record (MAR). Patient demographics were extracted from either the medication chart or the hospital patient information system. Height and weight were used to calculate BMI based on the formula: weight (kg)/[height (meters).[2,15] Neonatal intensive care medical records were not available at our campus site; thus, no neonatal records were reviewed.

Per institution standard, all recorded doses of resuscitation medications were assumed to follow the AHA 2000 and 2005 PALS guidelines.[2,16] To assess for treatment group effects, the recorded doses of the administered medications were compared against the following dose calculations: 1) the patient's ABW in kg, 2) the patient's IBW in kg, and 3) the weight correlated with the patient's height as recommended by the 2007 Edition B BPET. Patients served as their own controls. The absolute differences in all three dosages were calculated and recorded (Table). Dose estimations that varied by at least 10 percent from the administered dose were prospectively considered to be clinically significant.[5] A potential medication error was prospectively defined as a dose difference greater than 20 percent.[17] Outcomes of cardiopulmonary resuscitations were not evaluated. This study was approved by the Institutional Review Boards of UMMMC and the Massachusetts College of Pharmacy and Health Sciences, and written informed consent was not required.

RESULTS

A total of 54 consecutive patients were evaluated for inclusion and 50 patients were excluded from analysis (Figure). The four patients included were overweight, and none were obese. The cohort included two males and two females with

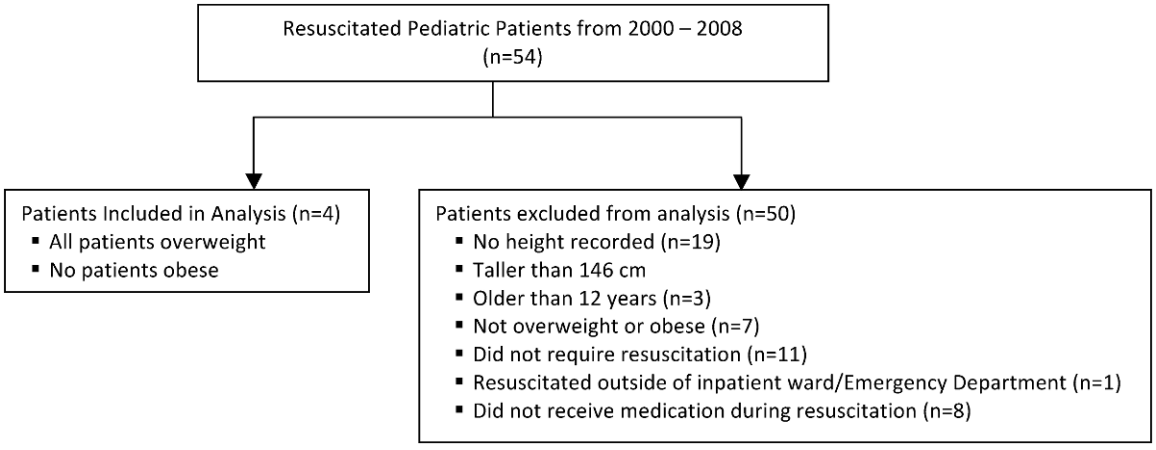

Figure. Patients Included and Excluded From Analysis

ages ranging from 40 weeks to 11 years.

Each patient in the study received at least two different medications during their emergency resuscitation and one patient received four different medications. The table lists the potential doses based on ABW, IBW or the BPET recommended doses. Each patient received at least one dose of epinephrine, three patients received sodium bicarbonate, one patient received amiodarone and one patient received atropine (10 medications total). All medications were administered intravenously. At least one administered medication dose differed by more than 10% from doses recalculated using ABW and IBW as well as the dose recommended by the BPET in each patient. In addition, 4 out of 10 doses recalculated with ABW, 8 out of 10 doses recalculated with IBW and 8 out of 10 doses recommended by the BPET differed by more than 20% from the administered dose.

The largest dosing differences were observed upon comparison of the administered dose versus the dose recommended by the BPET. For example, a 300% dose difference was recorded for Patient 3 comparing the actual administered epinephrine dose of 0.1 mg IV and the BPET recommended dose of 0.4 mg IV. All patient weights were represented on the BPET.

DISCUSSION

The increasing national prevalence of overweight children led us to initially evaluate our practice of using weight-based dosing of resuscitation medications during emergency situations. This pilot study resulted from the need to evaluate dosing strategies used during pediatric emergency resuscitations in light of the growing obesity trends in the United States. Although only 4 out of 54 possible patients (approximately 7.5%) were included in the analysis, this percentage remains below national averages for the prevalence of overweight children. Based upon national averages, we were expecting between 9% and 15.7% of our total population to be included. Additionally, one of the included patients was less than 2 years old, which, if excluded, further reduces our percentage below national averages.

All pediatric code carts at UMMMC include the 2007 Edition B BPET; however, interviews with our pediatric healthcare providers reveal that the BPET may not be routinely used during emergency situations. Our results suggest that pediatric healthcare providers at UMMMC dose emergency resuscitation medications according to ABW based upon PALS guidelines. Of note, some specific weights are not represented on the BPET. Although the dosing category can be assumed based on height using the BPET, any patient in our study with a weight not represented on the BPET could not have had comparator doses calculated according to our study methods. In our study, all patient weights were represented on the BPET.

Our study results revealed that each patient included was at risk for a potential medication error with one or more medications received during the resuscitation event when several dosing strategies were compared, further demonstrating the need to standardize dosing practices in overweight patients. Overall, approximately

10% of children treated in the emergency department experience medication errors, and the risk of experiencing an error is greater for children requiring resuscitation and emergency stabilization.[17-19] The PALS guidelines are referenced as the standard of care for appropriate dose and equipment recommendations during these emergencies.[2] Moreover, ABW is frequently used for medication dosing. Although it may be appropriate to consult the child's parent/guardian for a weight approximation, studies have reported mixed results as to the reliability of these sources for weight estimates during times of stress.[20-22] Other methods of estimating a child's weight include age-based formulas and those which may consider body habitus (slim, average, heavy). A study by Black et al. in 2002 compared six methods used to calculate a child's weight and found that length-based methods were the most accurate in predicting weight.[23] However, it is unknown if length-based methods remain the most accurate method for weight prediction in children in light of the increasing prevalence of pediatric obesity.

Another study compared the use of the BPET to a standardized volume-to-weight-based dose reformulation of medications in 3 simulated emergency scenarios. Focusing specifically on the time to drug delivery and incidence of dosing error, the investigators reported that the proportion of dosing errors with the BPET were greater than with the volume-to-weight-based dosing in all 3 scenarios. Moreover, the study found that the BPET-defined medication doses accurately predicted medication doses in only 55% to 60% of the cases where it was used.[24] Similarly, our study showed that the BPET tape would have resulted in potential medication errors for all our overweight patients if they received its recommended doses, compared to doses calculated on actual body weight. Other potential errors with the BPET have been previously described.[25,26] However, the argument has been made that the patient will be placed in the correct zone for weight more than 50% of the time and that clinical judgment should be used when adapting the BPET to various body types.[13,27] Specifically, if a child appears larger than the weight range on the measured color-zone, the next larger color category can be used to compensate for the obesity.[3]

A recently published pediatric study sought to describe the incidence and types of medication prescribing errors in the emergency department.[17] The authors concluded that when a drug regimen differed by at least 20% from the recommended dose, a potential medication error occurred. In our study population, all doses recommended by the BPET differed by more than 20% from the administered dose based on the patient's ABW, resulting in a potential medication error, and 3 of the 4 study patients would have been underdosed by the BPET. However, because patient outcomes were not assessed, the significance of this unknown.

Patient and drug-specific factors should also be considered in determining a medication dose that will provide the greatest therapeutic effect with the least amount of risk. For example, volume of distribution (Vd) is dependent upon lipophilicity; a child with more adipose tissue may require a higher dose of a lipophilic medication to achieve the desired effect. As such, a patient's ABW would be an important factor to consider in drug dosing. The concept of Vd may be helpful in deciding whether dose discrepancies occur in overweight and obese pediatric patients when the BPET is used. Many resuscitation drugs such as epinephrine, phenytoin, sodium bicarbonate, calcium and adenosine are hydrophilic and have small Vds[28-32] for which some may argue doses should be based on lean weight, not ABW. Factors that influence dosing should be thoroughly considered in the infant population as well. This study included one neonatal patient resuscitated outside of a neonatal intensive care unit, and a general limitation to inclusion of this patient in the study is that factors that influence drug dosing may differ from the general pediatric population.

Alternatively, some resuscitation medications, including amiodarone, are highly lipophilic.[33,34] It should be noted, however, that many fat-soluble medications require time to distribute from the central compartment to the adipose tissue and that an initial bolus (typically administered during an emergency) based on ABW has the theoretical potential of producing acute toxic concentrations.[13] It has been postulated that dosing based on lean body weight may not account for the numerous variables in patient characteristics and drug pharmacokinetics, however, this has not been studied.[35] While dosing based upon pharmacokinetic properties may have theoretical basis, it has not been well studied and may not

directly translate to patient outcomes.

Finally, this pilot study differs from several other approaches to assessing practice variables for emergency medicine administration, from the perspective that it uses actual patient data. Other studies have examined similar issues using a simulated design.[34,35] Following the completion of a simulated study that showed that the BPET reduced deviation from a recommend dose, Shah and colleagues urged that studies be conducted in the clinical setting to confirm this finding.[34]

Several factors limited our study results due to its retrospective nature. Reliable data was only available from year 2000 to the current time, as the year 2000 marked a transition in the format of the hospital's record-keeping system. Other limitations included a lack of documented patient data, lack of information regarding prescriber decision support during medication dosing, and inability to appropriately assess patient outcomes. A majority of the patient medical records reviewed did not contain patient height data, prohibiting our ability to calculate BMI. In addition, So and colleagues demonstrated that other methods besides the BPET may be useful in obtaining accurate weight estimations in children; these methods were not considered in our study.[36] Other limitations included our reliance on ICD-9 coding to correctly identify patients for potential inclusion and the high prevalence of other situations documented on resuscitation reports that did not require medication use.

CONCLUSION

This pilot analysis demonstrated that differences in cardiopulmonary resuscitation medication dosing exist in overweight children when three different dosing strategies were compared to the actual dose received. Each patient represented in this study showed that at least one potential medication dosing error could have occurred when the three different dosing estimates were compared to the actual dose received. As patient outcomes were not assessed, the clinical significance of dose differences shown in our study remains unknown. This hypothesis-generating study supports the need for a larger trial demonstrating a consistent, evidence-based approach to drug dosing in overweight children during cardiopulmonary resuscitation.

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